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European Innovation Scoreboard: strategies to measure country progress over time.

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Introduction

In the following chapters we examine possible alternatives to the current approach used in the European Innovation Scoreboard (EIS) to measure country progress in innovation performance over time. The quantitative approach used to assess country performance is the Summary Innovation Index. The methodology to calculate the SII scores and the SII growth rates is explained in the technical annex of the EIS 2007 report, therefore it is not reported here.

We briefly recall the basic steps to calculate the SII growth rate. The SII growth rate is based on the SII values over a 5-year period. Such SII values are calculated using the min/max normalization technique (see below), using the overall minima and maxima scores across the full 5 years and across the EU27 + EFTA countries for each component indicator. Moreover, some identified outliers have been excluded from the calculation of the minima and maxima.

Finally, as the EIS report says, <<… the growth rate of the SII is calculated as the annual percentage change between the SII at time t and the average over the preceding three years, after a one-year lag (i.e., t-4, t-3 and t-2). The three-year average is used to reduce year-to-year variability; the one-year lag is used to increase the difference between the average for the three base years and the final year and to minimize the problem of statistical / sampling variability.>>.

In the first part of this report we examine whether available re-scaling approaches (i.e. indicization and normalization) are compatible with the formulas for the calculation of SII growth rates. So, we will revisit both min/max normalization and z-scores techniques and analyze their feasibility for the subsequent calculation of SII growth rates. In the second part, we will focus on the different ways to calculate growth rates, and the different meanings of the corresponding outcomes. We provide examples using the data available on the EIS 2007 Excel spreadsheet.

We do not recommend specific approaches, yet we highlight which combinations of indicization, normalization and growth rate calculation should be avoided.

The focus of the report is to raise discussion among the participants to the workshop of June 16, 2008 upon the relative merits and limitations of these approaches, with the idea to identify potential candidates for further improvements of the SII. The report is an overview of approaches that are in principle applicable to any given dataset. The report is not a feasibility study of a specific technique to the EIS dataset, for which more detailed analyses would be required given the constraints dictated by the quality of the dataset, including the presence of missing values.

1 Re-scaling approaches

By re-scaling we mean any algebraic transformation of the indicators' raw values that is useful for preparing the indicators to the subsequent weighting/aggregation. In particular, we examine indicization and normalization.

1.1 Current procedure of indicization

An indicization transforms the raw values into values that are related to a reference index of, say, 100. We revisit the current indicization procedure used in the SII for the component indicators. At present, for a given country *c*, the value y_{ic} of indicator *i* is divided by the value of the same indicator for EU 27 (i.e. y_{iEU}) and multiplied by 100 in order to obtain an indicized value.

$$z_{ic} = 100 \frac{y_{ic}}{y_{iEU}} \tag{1}$$

If the indicized value is 100 it means that the indicator for that country performs as the EU27. If the indicized value is larger than 100, it means that the country performs better than the EU27. With this type of indicization, which is repeated independently for each year of analysis, it is not possible to appreciate any absolute change in country performance, as the values have all been relativized to EU27. So, if we want to quantify absolute changes in performance over time we have to consider this process with care (see discussion in section 1.5).

1.2 Current procedure of normalization

In addition, the current approach used to normalize the component indicators in order to build the SII consists in normalizing the scores of each indicator z_{ic} by using the so-called min-max normalization. This consists in subtracting the lowest indicator value found in the group of countries $z_{i,\min}$ and then dividing by the difference between the highest $z_{i,\max}$ and the lowest $z_{i,\min}$ values found within the same group of countries:

$$x_{ic} = \frac{z_{ic} - z_{i,\min}}{z_{i,\max} - z_{i,\min}} \tag{2}$$

The maximum re-scaled score is equal to 1 and the minimum value is equal to 0.

To assess absolute changes in performance over time, the min-max normalization approach has to be used with care. Given that the scores are available over a number of years z_{ic}^{t}, the minimum and the maximum values for each indicator across the countries have to be found across all the years:

$$z_{i,Min} = \min_{\forall t,\forall c} \left\{ z_{i,c}^{t} \right\}$$
$$z_{i,Max} = \max_{\forall t,\forall c} \left\{ z_{i,c}^{t} \right\} \quad (3)$$

These overall minimum $z_{i,Min}$ and maximum $z_{i,Max}$ have to be used for the normalization:

$$x_{ic}^{t} = \frac{z_{ic}^{t} - z_{i,Min}}{z_{i,Max} - z_{i,Min}} \quad (4)$$

The overall minima and maxima of the indicators across years 2005, 2006 and 2007 are reported in Table 1. These minima and maxima are calculated on the raw indicators y_{ic} across all EU 27 + EFTA countries, thus excluding HR, TR, US, JP, IL,CA and AU.

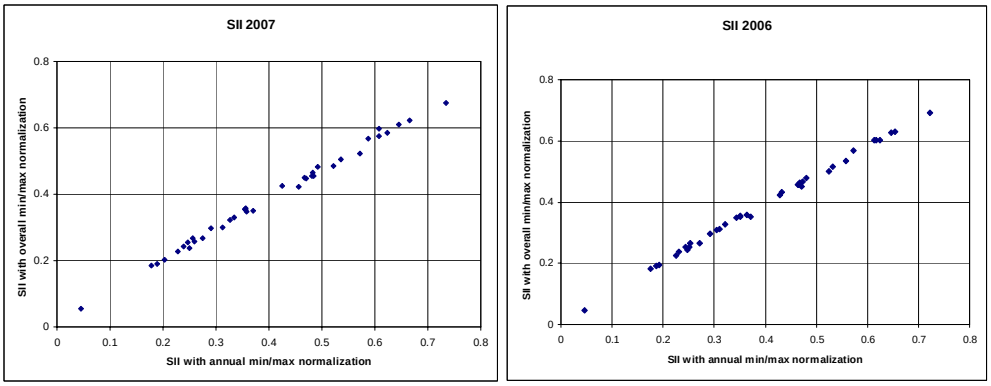
		OVERALL MIN	OVERALL MAX
1.1	S&E graduates	1.80	24.50
1.2	Population with tertiary education	10.44	35.14
1.3	Broadband penetration rate	0.20	29.60
1.4	Participation in life-long learning	1.30	32.10
1.5	Youth education attainment level	49.00	96.20
2.1	Public R&D expenditures	0.17	1.17
2.2	Business R&D expenditures	0.08	2.93
2.3	Share of medium-high/high-tech R&D	68.12	92.72
2.4	Enterprises receiving public funding for innovation	0.32	39.31
3.1	SMEs innovating in-house	9.32	37.32
3.2	Innovative SMEs co-operating with others	2.83	20.77
3.3	Innovation expenditures	0.73	3.47
3.4	Early-stage venture capital	0.00	0.22
3.5	ICT expenditures	4.90	9.90
3.6	SMEs using organizational innovation	11.01	58.43
4.1	Employment in high-tech services	1.37	5.13
4.2	Exports of high technology products	2.35	55.90
4.3	Sales of new-to-market products	1.90	13.55
4.4	Sales of new-to-firm products	1.57	10.03
4.5	Employment in medium-high/high-tech manufacturing	0.98	10.75
5.1	EPO patents per million population	1.17	425.64
5.2	USPTO patents per million population	0.00	167.49
5.3	Triad patents per million population	0.00	81.90
5.4	Community trademarks per million population	0.26	901.97
5.5	Community industrial designs per million population	0.00	398.03

Table 1: overall minima and maxima of the raw indicators across years 2005, 2006 and 2007 for the EU27 + EFTA countries.

When a new year of data becomes available, it may happen that the overall minimum or maximum across countries, for one or more indicators, changes. In such case, if the indicators are normalized using the existing overall maximum and minimum, it may be that some values are below 0 or above 1. If this happens, the CI can still be computed and the comparability across

time is not affected. However, it is common practice to avoid this to happen; therefore, the overall minimum and/or maximum are updated and the whole SII is recalculated across the past years. In this way, the SII maintains comparability across time, yet the past values of the SII could have changed.

In Figure 1, the SII calculated using the overall min/max normalization scheme across the latest three years (data for 2004, 2005, 2006) is plotted against the classic SII values obtained with a min/max normalization carried out for each year independently. It can be noticed that the SII scores and rankings are quite stable to the generalization of the normalization scheme (only 0.02 maximum difference of scores in 2005, 0.03 in 2006 and 0.06 in 2007). In all years, the rankings of few countries differ of 2, 3 positions as function of the normalization adopted (see for example Australia and Estonia in Table 2.1, Iceland in Table 2.2, and Estonia, Norway, Slovenia in Table 2.3).



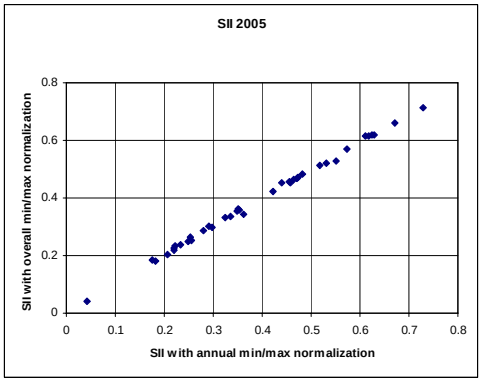


Figure 1. The SII calculated using the overall min/max normalization scheme across the latest three years 2005, 2006 and 2007 (data for 2004, 2005, 2006) is plotted against the classic SII values obtained with a min/max normalization carried out for each year independently.

with overall min/max norm.			**with annual min/max norm.**	
SE	0.71		SE	**0.73**
CH	0.66		CH	**0.67**
FI	0.62		FI	**0.63**
JP	0.62		JP	**0.62**
DK	0.62		DK	**0.62**
IL	0.61		IL	**0.61**
DE	0.57		DE	**0.57**
LU	0.53		LU	**0.55**
UK	0.52		UK	**0.53**
US	0.52		US	**0.52**
IE	0.48		IE	**0.48**
BE	0.47		BE	**0.47**
NL	0.47		NL	**0.47**
AT	0.47		AT	**0.46**
FR	0.46		IS	**0.46**
IS	0.45		FR	**0.46**
CA	0.45		CA	**0.44**
EU	0.42		EU	**0.42**
AU	0.36		EE	**0.36**
NO	0.36		NO	**0.35**
SI	0.36		AU	**0.35**
EE	0.35		SI	**0.35**
CZ	0.34		CZ	**0.34**
IT	0.33		IT	**0.32**
ES	0.30		CY	**0.30**
CY	0.30		ES	**0.29**
MT	0.29		MT	**0.28**
EL	0.27		LT	**0.26**
LT	0.25		EL	**0.25**
HU	0.25		HU	**0.25**
SK	0.24		SK	**0.23**
PT	0.23		PT	**0.22**
PL	0.23		PL	**0.22**
BG	0.22		BG	**0.22**
HR	0.21		HR	**0.21**
RO	0.18		LV	**0.18**
LV	0.18		RO	**0.18**
TR	**0.04**		**TR**	**0.04**

Table 2.1: Country scores and rankings for SII for year 2005 with annual and overall min/max normalization

with overall min/max norm.			**with annual min/max norm.**	
SE	0.69		SE	**0.72**
FI	0.63		FI	**0.65**
CH	0.63		CH	**0.65**
DK	0.60		DK	**0.62**
IL	0.60		IL	**0.62**
JP	0.60		JP	**0.61**
DE	0.57		DE	**0.57**
LU	0.54		LU	**0.56**
UK	0.52		UK	**0.53**
US	0.50		US	**0.52**
IE	0.48		IE	**0.48**
BE	0.47		BE	**0.47**
AT	0.46		IS	**0.47**
FR	0.46		AT	**0.47**
NL	0.46		FR	**0.47**
IS	0.45		NL	**0.46**
CA	0.43		CA	**0.43**
EU	0.42		EU	**0.43**
NO	0.36		EE	**0.37**
SI	0.36		NO	**0.36**
EE	0.35		SI	**0.35**
AU	0.35		AU	**0.35**
CZ	0.35		CZ	**0.34**
IT	0.33		IT	**0.32**
CY	0.31		CY	**0.31**
ES	0.31		ES	**0.30**
MT	0.30		MT	**0.29**
LT	0.27		LT	**0.27**
EL	0.26		EL	**0.25**
HU	0.25		HU	**0.25**
SK	0.25		PT	**0.25**
PT	0.25		SK	**0.24**
PL	0.24		PL	**0.23**
BG	0.23		BG	**0.22**
HR	0.20		HR	**0.19**
LV	0.19		LV	**0.19**
RO	0.18		RO	**0.17**
TR	**0.05**		**TR**	**0.05**

Table 2.2: Country scores and rankings for SII for year 2006 with annual and overall min/max normalization

with overall min/max norm.			**with annual min/max norm.**	
SE	0.74		SE	**0.67**
CH	0.67		CH	**0.62**
FI	0.64		FI	**0.61**
IL	0.62		JP	**0.6**
DK	0.61		IL	**0.59**
JP	0.61		DK	**0.57**
DE	0.59		DE	**0.57**
UK	0.57		UK	**0.52**
LU	0.54		LU	**0.51**
US	0.52		US	**0.49**
IE	0.49		IE	**0.48**
IS	0.48		AT	**0.47**
AT	0.48		NL	**0.46**
NL	0.48		IS	**0.45**
FR	0.47		BE	**0.45**
BE	0.47		FR	**0.45**
EU	0.46		CA	**0.42**
CA	0.43		EU	**0.42**
EE	0.37		CZ	**0.36**
NO	0.36		SI	**0.36**
CZ	0.36		AU	**0.35**
AU	0.36		EE	**0.35**
SI	0.35		NO	**0.35**
IT	0.33		IT	**0.33**
CY	0.33		CY	**0.32**
ES	0.31		ES	**0.3**
MT	0.29		MT	**0.3**
LT	0.27		EL	**0.27**
HU	0.26		LT	**0.27**
EL	0.26		HU	**0.26**
PT	0.25		SK	**0.25**
SK	0.25		PL	**0.24**
PL	0.24		PT	**0.24**
BG	0.23		BG	**0.23**
HR	0.2		HR	**0.2**
LV	0.19		LV	**0.19**
RO	0.18		RO	**0.18**
TR	**0.05**		**TR**	**0.05**

Table 2.3: Country scores and rankings for SII for year 2007 with annual and overall min/max normalization

1.3 The z-scores normalisation method

An alternative approach to normalise the indicators can be used to assess absolute changes in performance over time. This approach is called z-scores and has been applied, for instance, by DG-RTD to develop their composite indicators of knowledge-based economy. With a view to allow comparisons between years, the raw values y_{ic}^{t} of each indicator *i* for country *c* at time *t* are standardised using their mean y_{iEU}^{0} and their standard deviation σ_{iEU}^{0} across the European countries (excluding the EU aggregate) for the reference year *t=0*.

$$x_{ic}^{t} = \frac{y_{ic}^{t} - y_{iEU}^{0}}{\sigma_{iEU}^{0}} \tag{5}$$

The advantage of this method as opposed to the min-max method is that we do not need to update the normalisation parameters when a new year of data becomes available, given that the EU mean and standard deviation are constant and, therefore, no recalculation of the SII is required.

The results of the SII calculated with the z-scores normalization approach are reported in Table 3 for the years 2005, 2006 and 2007. Of course, EU in 2005 has zero score. We can appreciate the trend of each country across the years as well as their relative position to the EU. For instance, Italy in 2007 has the same score (hence performance) of the EU average in 2005. Luxembourg has an extremely high value of the SII. This is due to the very high value of the indicator 'Community trademarks per million population' for all years; we have not corrected for this outlier as was done with the min/max normalization approach.

In Table 3 it is straightforward to appreciate the trend of each country over the three years and the relative position with respect to the EU in 2005 (which has zero score). The absolute values of the SII are completely different from the previous case where the min/max normalization is used. On the right side of the table the normalization is carried out using formula 6. Here it is not possible to appreciate the time trend of each country any more but it is possible to calculate the spread of the countries scores at a given year on the basis of their standard deviations. Calculations show that the standard deviation is slightly increasing with time, meaning that the countries performances tend to widen as time increases.

1.3.1 An alternative approach

An alternative approach is to use, for each year *t*, the corresponding mean value y_{iEU}^{t} while maintaining the standard deviation at its value of the reference year σ_{iEU}^{0}.

$$x_{ic}^{t} = \frac{y_{ic}^{t} - y_{iEU}^{t}}{\sigma_{iEU}^{0}} \tag{6}$$

In this way, each indicator is standardised differently for each year; therefore, we can not appreciate the time trend of the SII any more, but we get an indication of the spread of the countries SII's at each time point. This might be useful to measure the level of convergence of countries in innovation performance. In particular we found that the standard deviation slightly increases with time, meaning that the countries performances tend to widen as time increases.

SII with z-scores normalization (**formula 5**)				SII with z-scores normalization (**formula 6**)			
	2005	2006	2007		2005	2006	2007
EU	0.00	0.01	0.03	**EU**	0.00	0.00	0.00
BE	0.02	0.04	0.04	**BE**	0.02	0.03	0.01
BG	-0.25	-0.24	-0.23	**BG**	-0.25	-0.25	-0.26
CZ	-0.12	-0.11	-0.09	**CZ**	-0.12	-0.12	-0.12
DK	0.20	0.22	0.25	**DK**	0.20	0.21	0.22
DE	0.24	0.25	0.29	**DE**	0.24	0.24	0.26
EE	-0.13	-0.12	-0.10	**EE**	-0.13	-0.13	-0.14
IE	0.08	0.06	0.09	**IE**	0.08	0.05	0.06
EL	-0.18	-0.18	-0.17	**EL**	-0.18	-0.19	-0.21
ES	-0.16	-0.14	-0.13	**ES**	-0.16	-0.15	-0.16
FR	0.03	0.04	0.06	**FR**	0.03	0.03	0.02
IT	-0.04	-0.02	0.00	**IT**	-0.04	-0.03	-0.03
CY	-0.11	-0.09	-0.01	**CY**	-0.11	-0.10	-0.05
LV	-0.24	-0.22	-0.21	**LV**	-0.24	-0.23	-0.25
LT	-0.19	-0.17	-0.16	**LT**	-0.19	-0.19	-0.20
LU	0.43	0.60	0.61	**LU**	0.43	0.59	0.57
HU	-0.15	-0.15	-0.15	**HU**	-0.15	-0.16	-0.18
MT	-0.29	-0.28	-0.22	**MT**	-0.29	-0.29	-0.26
NL	0.13	0.13	0.16	**NL**	0.13	0.11	0.13
AT	0.14	0.14	0.20	**AT**	0.14	0.13	0.17
PL	-0.21	-0.19	-0.18	**PL**	-0.21	-0.20	-0.21
PT	-0.24	-0.23	-0.19	**PT**	-0.24	-0.24	-0.22
RO	-0.26	-0.34	-0.33	**RO**	-0.26	-0.35	-0.36
SI	-0.09	-0.10	-0.07	**SI**	-0.09	-0.11	-0.11
SK	-0.19	-0.18	-0.17	**SK**	-0.19	-0.19	-0.20
FI	0.21	0.23	0.24	**FI**	0.21	0.21	0.21
SE	0.26	0.28	0.32	**SE**	0.26	0.27	0.28
UK	0.08	0.09	0.12	**UK**	0.08	0.08	0.08
HR	-0.25	-0.25	-0.25	**HR**	-0.25	-0.27	-0.30
TR	-0.55	-0.54	-0.53	**TR**	-0.55	-0.56	-0.59
IS	-0.12	-0.11	-0.03	**IS**	-0.12	-0.13	-0.07
NO	-0.11	-0.11	-0.10	**NO**	-0.11	-0.12	-0.13
CH	0.40	0.41	0.50	**CH**	0.40	0.40	0.46
US	0.18	0.19	0.20	**US**	0.18	0.17	0.15
JP	0.24	0.24	0.25	**JP**	0.24	0.22	0.19
IL	0.21	0.21	0.21	**IL**	0.21	0.19	0.17
CA	-0.08	-0.07	-0.06	**CA**	-0.08	-0.09	-0.12
AU	-0.25	-0.25	-0.22	**AU**	-0.25	-0.26	-0.27

Table 3: SII obtained with the z-scores normalization approach and formula 5.

1.4 Composite indicator formula

Letting aside the problem of weights selection and discussions upon the choice of the aggregation rule (here we simply use linear aggregation), which is not the focus here, the composite indicator I_c^t for country c at time t is the sum of the m component indicators x_{ic}^t:

$$I_c^t = \sum_{i=1}^{m} w_i x_{ic}^t \qquad (7)$$

weighted by the coefficients w_i, which are selected such that $\sum_{i=1}^{m} w_i = 1$.

2 Calculating growth rates

Let us now come closer to the focus of this work, which is to propose some feasible options for assessing changes in country performances over time. Once the composite indicator is calculated for a number of years, it is easy to observe changes and trends in its values without going in too complex calculations. In this chapter we define the growth rate of a composite indicator both in relative terms (as percentage change with respect to the previous year or to a number of years in the past) and in absolute terms (the so called rate of change, as difference between the CI score at present and the CI score a number of years in the past), as well as composite growth rates, useful to provide complementary information (see section 2.3), and an approach to measure growth based on distance to target (see section 2.5).

2.1 Growth rate of a composite indicator

Each country is, at any given time, characterised by a value of the composite indicator which can be compared with the initial value at the reference year. The annual growth rate of the composite indicator between two consecutive years *t-1* and *t* is simply given by:

$$v_c^{t-1,t} = \frac{I_c^t}{I_c^{t-1}} - 1. \tag{8}$$

The overall growth rate of the composite indicator between year *0* and year *t* is:

$$v_c^{0,t} = \frac{I_c^t}{I_c^{t-1}} \frac{I_c^{t-1}}{I_c^{t-2}} \cdots \frac{I_c^1}{I_c^0} - 1 = \frac{I_c^t}{I_c^0} - 1. \tag{9}$$

It is also possible to define the annual average growth rate of the composite indicator between year *0* and year *t*:

$$\upsilon_c^{0,t} = \left(\frac{I_c^t}{I_c^0} \right)^{1/t} - 1 \tag{10}$$

In Table 4 we calculate the annual growth rate (formula 8) of the SII between 2005 and 2006 and between 2006 and 2007 using the overall min/max normalization (formula 4). In the last column of Table 4 we also calculate the annual average growth rate (formula 10) between 2005 and 2007.
Given that each component indicator is indicized (i.e. relative to the EU score, according to formula 1), with respect to the same year, it is not possible to see any trend in the scores. For example, the scores for EU are always 0.42, which corresponds to a false zero annual growth rate. For this reason the growth rates in Table 4 are not meaningful.
Therefore, to obtain meaningful growth rate figures, each component indicator should be relative to the EU score at the starting year (e.g. 2005) before the normalization. Table 5 shows the SII scores, their annual growth rates and the average annual growth rates, when the single indicators are scaled to the EU score at 2005. Here we can observe that the EU annual growth is 3% between 2005 and 2006, and 7% between 2006 and 2007. The average annual growth rate between 2005 and 2007 is 5%. The extremely high growth rate for Turkey between 2005 and 2006 is due to its considerable improvement from the score 0.03 in 2005 to the score 0.04 in 2006. Note that the SII country scores at year 2005 in Tables 4 and 5 differ because $z_{i,Min}, z_{i,Max}$ (i.e. the overall minima and maxima) are different. Indeed, these latter are obtained from the different definitions used by the two approaches (i.e., $z_{ic}^t = 100 \frac{y^t{}_{ic}}{y^t{}_{iEU}}$ vs. $z_{ic}^t = 100 \frac{y^t{}_{ic}}{y^0{}_{iEU}}$) .

SII with overall min/max normalization (**formula 4**)				annual growth rate (**formula 8**)		**average annual growth rate (**formula 10**)**
	2005	2006	2007	05 ->06	06 -> 07	**05 -> 07**
EU	0.42	0.42	0.42	0.00	0.00	**0.00**
BE	0.47	0.47	0.45	-0.01	-0.03	**-0.02**
BG	0.22	0.23	0.23	0.03	0.01	**0.02**
CZ	0.34	0.35	0.36	0.03	0.03	**0.03**
DK	0.62	0.60	0.57	-0.02	-0.05	**-0.03**
DE	0.57	0.57	0.57	-0.01	0.00	**0.00**
EE	0.35	0.35	0.35	0.02	-0.01	**0.01**
IE	0.48	0.48	0.48	-0.01	0.01	**0.00**
EL	0.27	0.26	0.27	0.00	0.01	**0.01**
ES	0.30	0.31	0.30	0.02	-0.02	**0.00**
FR	0.46	0.46	0.45	0.00	-0.02	**-0.01**
IT	0.33	0.33	0.33	-0.01	0.00	**0.00**
CY	0.30	0.31	0.32	0.04	0.04	**0.04**
LV	0.18	0.19	0.19	0.05	0.00	**0.03**
LT	0.25	0.27	0.27	0.05	0.01	**0.03**
LU	0.53	0.54	0.51	0.01	-0.06	**-0.02**
HU	0.25	0.25	0.26	0.02	0.02	**0.02**
MT	0.29	0.30	0.30	0.04	0.00	**0.02**
NL	0.47	0.46	0.46	-0.02	0.00	**-0.01**
AT	0.47	0.46	0.47	0.00	0.00	**0.00**
PL	0.23	0.24	0.24	0.05	0.02	**0.04**
PT	0.23	0.25	0.24	0.06	-0.03	**0.01**
RO	0.18	0.18	0.18	-0.01	0.01	**0.00**
SI	0.36	0.36	0.36	0.00	0.00	**0.00**
SK	0.24	0.25	0.25	0.06	0.01	**0.03**
FI	0.62	0.63	0.61	0.02	-0.03	**-0.01**
SE	0.71	0.69	0.67	-0.03	-0.02	**-0.03**
UK	0.52	0.52	0.52	-0.01	0.01	**0.00**
HR	0.21	0.20	0.20	-0.05	0.04	**-0.01**
TR	0.04	0.05	0.05	0.15	0.16	**0.15**
IS	0.45	0.45	0.45	0.00	0.01	**0.00**
NO	0.36	0.36	0.35	0.00	-0.03	**-0.02**
CH	0.66	0.63	0.62	-0.05	-0.01	**-0.03**
US	0.52	0.50	0.49	-0.03	-0.03	**-0.03**
JP	0.62	0.60	0.60	-0.02	-0.01	**-0.02**
IL	0.61	0.60	0.59	-0.02	-0.03	**-0.02**
CA	0.45	0.43	0.42	-0.04	-0.02	**-0.03**
AU	**0.36**	**0.35**	**0.35**	**-0.03**	**0.00**	**-0.01**

Table 4. Annual growth rates (formula 8) of the SII between 2005 and 2006 and between 2006 and 2007 using the overall min/max normalization (formula 4). Here the component indicators of a given year are relative to the EU scores for the same year.

SII with overall min/max normalization (**formula 4**)				annual growth rate (**formula 8**)		**average annual growth rate (**formula 10**)**
	2005	2006	2007	05 -->06	06 -> 07	**05 -> 07**
EU	0.41	0.42	0.46	0.03	0.07	**0.05**
BE	0.45	0.46	0.46	0.03	-0.01	**0.01**
BG	0.22	0.22	0.23	0.04	0.02	**0.03**
CZ	0.33	0.35	0.36	0.05	0.04	**0.04**
DK	0.61	0.61	0.60	0.01	-0.02	**-0.01**
DE	0.56	0.57	0.58	0.01	0.03	**0.02**
EE	0.34	0.36	0.37	0.05	0.02	**0.04**
IE	0.47	0.48	0.49	0.01	0.03	**0.02**
EL	0.26	0.26	0.27	0.01	0.03	**0.02**
ES	0.29	0.30	0.32	0.07	0.05	**0.06**
FR	0.44	0.46	0.47	0.03	0.02	**0.03**
IT	0.32	0.33	0.34	0.03	0.04	**0.03**
CY	0.28	0.30	0.32	0.08	0.06	**0.07**
LV	0.17	0.19	0.19	0.09	0.02	**0.06**
LT	0.25	0.27	0.28	0.08	0.03	**0.05**
LU	0.50	0.56	0.53	0.11	-0.05	**0.03**
HU	0.24	0.25	0.26	0.04	0.04	**0.04**
MT	0.26	0.28	0.30	0.09	0.06	**0.07**
NL	0.44	0.45	0.47	0.01	0.05	**0.03**
AT	0.45	0.47	0.48	0.03	0.04	**0.03**
PL	0.22	0.24	0.24	0.06	0.04	**0.05**
PT	0.23	0.25	0.26	0.11	0.06	**0.08**
RO	0.18	0.18	0.19	0.00	0.02	**0.01**
SI	0.35	0.35	0.36	0.02	0.03	**0.02**
SK	0.23	0.25	0.25	0.06	0.03	**0.04**
FI	0.60	0.63	0.63	0.05	0.00	**0.02**
SE	0.71	0.70	0.72	-0.01	0.03	**0.01**
UK	0.52	0.53	0.56	0.02	0.05	**0.04**
HR	0.21	0.20	0.21	-0.04	0.04	**0.00**
TR	0.03	0.04	0.05	0.44	0.10	**0.26**
IS	0.42	0.44	0.47	0.06	0.06	**0.06**
NO	0.34	0.35	0.36	0.05	0.01	**0.03**
CH	0.61	0.63	0.65	0.03	0.04	**0.03**
US	0.52	0.52	0.53	0.02	0.02	**0.02**
JP	0.60	0.61	0.62	0.02	0.01	**0.01**
IL	0.57	0.59	0.61	0.03	0.04	**0.04**
CA	0.39	0.41	0.42	0.04	0.02	**0.03**
AU	**0.33**	**0.34**	**0.35**	**0.02**	**0.05**	**0.04**

Table 5. Annual growth rates (formula 8) of the SII between 2005 and 2006 and between 2006 and 2007 using the overall min/max normalization (formula 4). Here all the component indicators are relative to the EU scores for the starting year (i.e. 2005).

The formulas for the growth rates (formulas 8, 9 and 10) DO NOT SUIT the z-scores normalization (formula 5) and are not reported here. There are a number of reasons for that: (1) the reference value for EU in 2005 has a score of zero, (2) the formula does not work properly when countries have scores below the EU average (i.e. negative scores), and (3) when the country scores approach zero the growth rates tend to infinity.

2.2 The rate of change of a composite indicator

In alternative to the growth rate, which uses percentage variation of the CI scores over time, the *rate of change* provides CI variations in absolute terms. This is simply obtained by considering the ratio

$$\tau_c^{t-k,t} = \frac{I_c^t - I_c^{t-k}}{k}$$

The values for this rate of change can be rescaled in 5 categories (see [2]), defined as follows: “Significant progress” applies to those countries, which are progressing at rates above the average for all countries making progress. “Slight progress” applies to those countries, which are progressing at rates below the average for all countries making progress. “Stagnant” refers to those countries where no changes (or quantitatively insignificant changes) have been recorded over the period in question. “Slight regression” applies to those countries, which are regressing at rates below the average for all countries regressing (i.e. they are regressing more slowly). “Significant regression” applies to those countries, which are regressing at rates above the average for all countries regressing (i.e. they are regressing more rapidly). A graphical representation of the rate of change in the Basic Capabilities Index [1] is given in Figure 2.

TABLE 1. BCI and BCI evolution by countries' BCI level

CRITICAL LEVEL			VERY LOW LEVEL			LOW LEVEL			MEDIUM LEVEL			ACCEPTABLE LEVEL		
Country	BCI	BCI Evolution	Country	BCI	BCI Evolution	Country	BCI	BCI Evolution	Country	BCI	BCI Evolution	Country	BCI	BCI Evolution
Gambia	69.7	→	El Salvador	79.8	→	Egypt	99.8	→	United Arab Emirates	97.9	=	Japan	99.9	→
Bhutan	69.1	=	Iraq	79.0	→	Brazil	99.1	←	Croatia	97.4	=	Sweden	99.9	→
Lesotho	68.5	←	Djibouti	78.3		Tuvalu	98.7	=	Brunei Darussalam	97.4	=	Austria	99.8	→
Guinea	68.4	→	Morocco	78.1	→	Colombia	98.7	→	Lithuania	97.4	=	Belgium	99.8	→
Kenya	68.3	→	Sao Tomé and Prin.	77.8		Kiribati	98.1	=	Hungary	97.3		France	99.8	→
Eritrea	66.9	→	Philippines	77.3	→	South Africa	97.2	=	Belarus	97.2	=	Germany	99.8	→
Ghana	66.4	=	Swaziland	76.9	=	Syria	97.0	←	Luxembourg	97.1	←	Greece	99.8	→
Mali	65.8	→	Côte d'Ivoire	76.9	→	Maldives	96.4	→	Oman	97.0	→	Spain	99.8	→
Yemen	63.8	←	Zimbabwe	76.3	←	Peru	96.0	→	Qatar	97.0	=	Switzerland	99.8	→
Madagascar	63.5	→	Honduras	76.3	→	Namibia	95.8	←	Samoa	97.0	=	Denmark	99.8	=
Uganda	63.0	→	Mauritania	75.3	→	Tajikistan	95.7	=	Bulgaria	96.9	→	Finland	99.8	=
Nigeria	62.8	=	Zambia	74.6	→	Paraguay	95.5	→	Russian Federation	96.8	=	New Zealand	99.8	→
Malawi	62.8	=	Nicaragua	74.0	→	Suriname	95.4	←	Ukraine	96.8	→	Iceland	99.8	=
Mozambique	60.8	→	Benin	73.3	←	Vanuatu	95.1	←	Macedonia	96.5	=	Israel	99.8	=
Pakistan	60.4	→	Myanmar	73.1	→	Dominican Rep.	94.9	←	Romania	96.3	=	Portugal	99.7	→
Cambodia	59.1	←	Papua New Guinea	72.9	→	Indonesia	94.9	→	Costa Rica	96.2	=	Norway	99.7	=
Equatorial G.	58.9	←	Comoros	72.5	=	Gabon	91.9	→	West Bank and Gaza	96.0	=	Ireland	99.7	=
Lao, PDR	58.0	→	Senegal	72.2	→	Guyana	91.2	←	Moldova	96.0	←	Netherlands	99.7	=
Bangladesh	57.1	=	Guatemala	71.7	→	Sudan	91.0	←	St. Lucia	95.9	←	Poland	99.6	=
Burundi	56.4	→	India	71.3	→	Ecuador	90.8	=	Lebanon	95.9	→	Malta	99.6	=
Nepal	54.8	→	Burkina Faso	71.1	→	Bolivia	90.2	→	Mongolia	95.8	→	Cyprus	99.6	=
Niger	54.6	=	Togo	70.2	=	Congo, Rep.	90.0		Kyrgyzstan	95.7	=	United Kingdom	99.5	→
Rwanda	51.3	→	Cameroon	70.2	←				Armenia	95.6	→	Czech Republic	99.3	=
Ethiopia	50.3	→	Tanzania	70.0	→				Uruguay	95.4	=	Chile	99.3	=
Chad	43.0	←							St. Vincent and Gren.	95.3	→	Bahrain	99.2	=

Figure 2: graphical representation of the rate of change in the Basic Capabilities Index, proposed by [1].

2.3 Composite growth rates

Complementary information to the growth rate of the composite indicator can be provided by evaluating a composite growth rate, i.e. a composite indicator of growth rates. This consists in taking the raw value y_{ic}^t (i.e. neither indicized nor normalised) of a component indicator *i* for country *c* at time *t*, and defining its growth rate τ_{ic}^t between 0 and *t* as the ratio $(y_{ic}^t / y_{ic}^0) = 1 + \tau_{ic}^t$. By applying the standard (linear) aggregation rule to these individual growth rates, we obtain:

$$1 + \tau_c^t = \sum_{i=1}^m w_i \frac{y_{ic}^t}{y_{ic}^0}, \tag{11}$$

where τ_c^t is called *composite growth rate for country c between 0 and t.*

Equivalently, τ_c^t can be evaluated by employing another formula that makes use of the normalised indicators x_{ic}^t:

$$1 + \tau_c^t = \sum_{i=1}^m w_i \frac{x_{ic}^t + x_i^0}{x_{ic}^0 + x_i^0}, \quad \text{with } x_i^0 = \frac{y_{iEU}^0}{\sigma_{iEU}^0} \tag{12}$$

This latter formula can be obtained from the previous using simple algebraic manipulation.

This approach to calculate the composite growth rates is not appropriate when there are both 'positive' and 'negative' component indicators. For 'positive' indicators large values denote better performance (eg gross domestic expenditure in R&D), while for 'negative' indicators the lower the better (e.g., at risk of poverty rate). Indeed, while for 'positive' indicators things are straightforward, for 'negative' indicators an unclear term appears at both nominator and denominator:

$$1 + \tau_c^t = \sum_{i=1}^m w_i \frac{2y_{iEU}^0 - y_{ic}^t}{2y_{iEU}^0 - y_{ic}^0} \tag{13}$$

In conclusion, the linear aggregation rule does not properly suit the calculation of composite growth rates.

2.4 A generalised formula for the composite growth rates

In order to overcome the limitation above, we suggest adopting a generalised approach for the calculation of the composite growth rates.

After defining the growth y_{ic}^t / y_{ic}^0 for each component indicator in terms of the ratio between the raw values at year *t* and year *0*, we then aggregate those growths using the weights in the form of a geometric average:

$$1 + \tau_c^t = \prod_{i \in I_1} \left(\frac{y_{ic}^t}{y_{ic}^0} \right)^{w_i} \cdot \prod_{i \in I_2} \left(\frac{y_{ic}^0}{y_{ic}^t} \right)^{w_i} \tag{14}$$

where I_1 and I_2 are the sets of the 'positive' and 'negative' indicators, respectively. Although the reader may be not acquainted with the idea of a geometric average, this easy formalism provides transparency in the way the composite growth rates are built. The composite growth rate τ_c^t so defined is invariant to any ratio-scale transformation and says how much the overall set of component indicators has progressed with respect to the reference year *t=0*.

Formula (14) can be used for both annual growth rates (i.e. between *t-1* and *t*) and multi-annual growth rates (e.g., between *t-2* and *t*). For the annual average growth rate between, e.g., *t-k* and *t*, the whole right hand side of formula (14) has to be powered to *1/k*.

The only problem with this formula is that a given indicator cannot change sign from one year to another. For example, for an indicator "balance of payments" this formula cannot be used.

In the SII there are only 'positive' indicators. The approach is very simple as it requires neither indicization (formula 1) nor normalization (e.g., formula 4). In addition, the presence of outliers for certain indicators for a given country across different years is not a problem, because their ratio corrects the outliers' effects. In conclusion, we recommend formula (14) to evaluate the composite growth rates. The first two columns in Table 6 show the annual composite growth rates between 2005 and 2006 and between 2006 and 2007. The third column shows the annual average composite growth rates between 2005 and 2007 using the rule given in formula (10). The results in Table 6 have been obtained by setting $w_i = 1/25$, as from the standard definition of the SII that employs equal weights. The results show that the EU has grown faster than both US, Japan, Australia and Canada in the period 2005 – 2007 (i.e. 4% growth). The fastest growth is that of Latvia and Cyprus.

	2005/2006	2006/2007	**average 2005/2007**
EU	0.03	0.06	**0.04**
BE	0.03	-0.02	**0.00**
BG	0.09	0.10	**0.09**
CZ	0.13	0.07	**0.10**
DK	0.01	-0.03	**-0.01**
DE	0.02	0.02	**0.02**
EE	-0.02	0.11	**0.04**
IE	0.03	0.04	**0.04**
EL	-1.00	0.08	**0.09**
ES	0.06	0.04	**0.05**
FR	0.03	0.03	**0.03**
IT	0.02	0.03	**0.02**
CY	0.11	0.10	**0.11**
LV	0.19	0.03	**0.11**
LT	0.01	0.05	**0.03**
LU	0.08	-0.03	**0.02**
HU	0.08	0.03	**0.05**
MT	0.08	0.13	**0.06**
NL	-0.04	0.10	**0.03**
AT	0.04	-0.02	**0.01**
PL	0.15	0.06	**0.10**
PT	0.07	0.05	**0.06**
RO	0.14	0.06	**0.10**
SI	-0.03	0.07	**0.02**
SK	0.07	0.10	**0.09**
FI	0.06	-0.01	**0.02**
SE	0.00	0.03	**0.02**
UK	0.02	0.10	**0.06**
HR	-0.06	-0.01	**-0.04**
TR	0.11	0.07	**0.09**
IS	0.06	0.03	**0.04**
NO	0.02	0.01	**0.02**
CH	0.02	0.04	**0.03**
US	0.01	0.02	**0.02**
JP	0.01	0.01	**0.01**
IL	-0.01	0.03	**0.01**
CA	0.02	0.01	**0.01**
AU	**0.00**	**0.06**	**0.03**

Table 6: Composite growth rates for the countries included in the EIS. The first column represents the composite growth rate between year 2005 and 2006. The second column is the composite growth rate between 2006 and 2007. Finally, the third column provides the average annual composite growth rates between 2005 and 2007.

2.5 Distance to target

If it is possible to set plausible targets for all component indicators then, using any of the measures of growth (or change) proposed above, we can calculate what should be the growth required for a given country to reach that targets. For example, the target could be reaching, in 2010, the 2007 top score for each indicator within the group of EU27 countries (e.g., 24.5 S&E graduates per million population in 2007 for Ireland, or 35.1 per million population with tertiary education in 2007 for Finland). So, formula (14) could be adjusted as follows:

$$1+\tau_c^t = \prod_{i \in I_1} \left(\frac{y_i^{top}}{y_{ic}^t} \right)^{w_i / 3}$$

where y_i^{top} is the raw value of indicator *i* for the best performing EU27 country in 2007, y_{ic}^t is the raw value of indicator I for country *c* at year *t=2007*, and the number *3* at the exponent indicates *1/(2010-2007)*, so that the average annual growth rate for each country can be calculated. The results of the expected average annual growth rate for each country are given in Table 7. For instance, the EU will have to grow, on average, 13% per year to reach, within 3 years, the 2007 top score in all indicators. Sweden has to grow only 6% per year to reach the top scores for all indicators, as this country is already top performing in many indicators, but not in all of them.

Country	**annual av. growth rate**
EU	**0.13**
BE	**0.16**
BG	**0.43**
CZ	**0.32**
DK	**0.10**
DE	**0.09**
EE	**0.26**
IE	**0.18**
EL	**0.58**
ES	**0.27**
FR	**0.12**
IT	**0.25**
CY	**0.34**
LV	**0.47**
LT	**0.52**
LU	**0.12**
HU	**0.40**
MT	**0.32**
NL	**0.11**
AT	**0.15**
PL	**0.59**
PT	**0.39**
RO	**0.56**
SI	**0.29**
SK	**0.62**
FI	**0.07**
SE	**0.06**
UK	**0.10**

Table 7: average annual growth rates required to reach in 2010 the best 2007 score in all indicators among EU27 countries.

3 Conclusions

This report examines possible alternatives to the current approach used in the European Innovation Scoreboard (EIS) to measure country progress in innovation performance over time. In the first part of this report we examined whether available re-scaling approaches (i.e. indicization and normalization) are compatible with the formulas for the calculation of SII growth rates. In the second part, we focused on the different ways to calculate growth rates, and the different meanings of the corresponding outcomes. We provided examples using the data available on the EIS 2007 Excel spreadsheet.

The focus of the report is to raise discussion among the participants to the workshop of June 16, 2008 upon the relative merits and limitations of these approaches, with the idea to identify potential candidates for further improvements of the SII.
As said, the report is an overview of approaches and tools that are in principle applicable to any given dataset. The report is not a feasibility study of a specific technique to the EIS dataset, for which more detailed analyses would be required given the constraints dictated by the quality of the dataset, including the presence of missing values.

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Abstract
In this report we examine possible alternatives to the current approach used in the European Innovation Scoreboard (EIS) to measure country progress in innovation performance over time. In the first part of this report we examine whether available re-scaling approaches (i.e. indicization and normalization) are compatible with the formulas for the calculation of SII growth rates. In the second part, we will focus on the different ways to calculate growth rates, and the different meanings of the corresponding outcomes. We provide examples using the data available on the EIS 2007 Excel spreadsheet.

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